Assessing the Impact of Space Weather on the Electric Power Grid Based on Insurance Claims for Industrial Electrical Equipment

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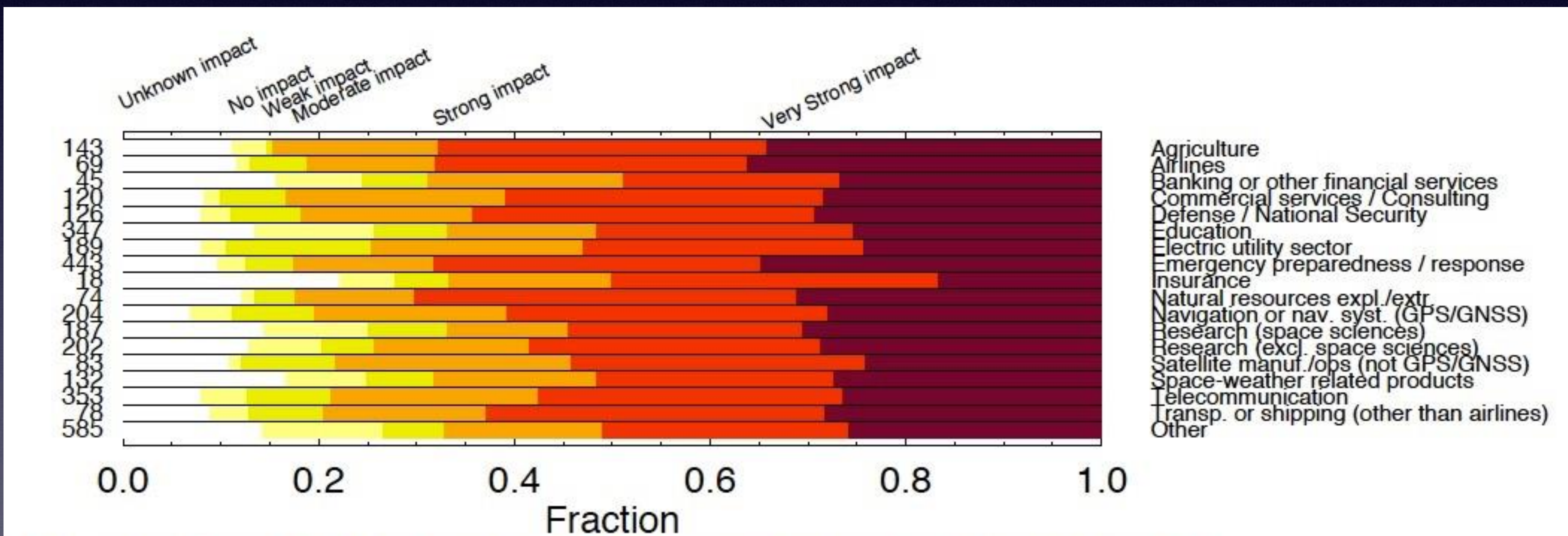
Space weather "customers"

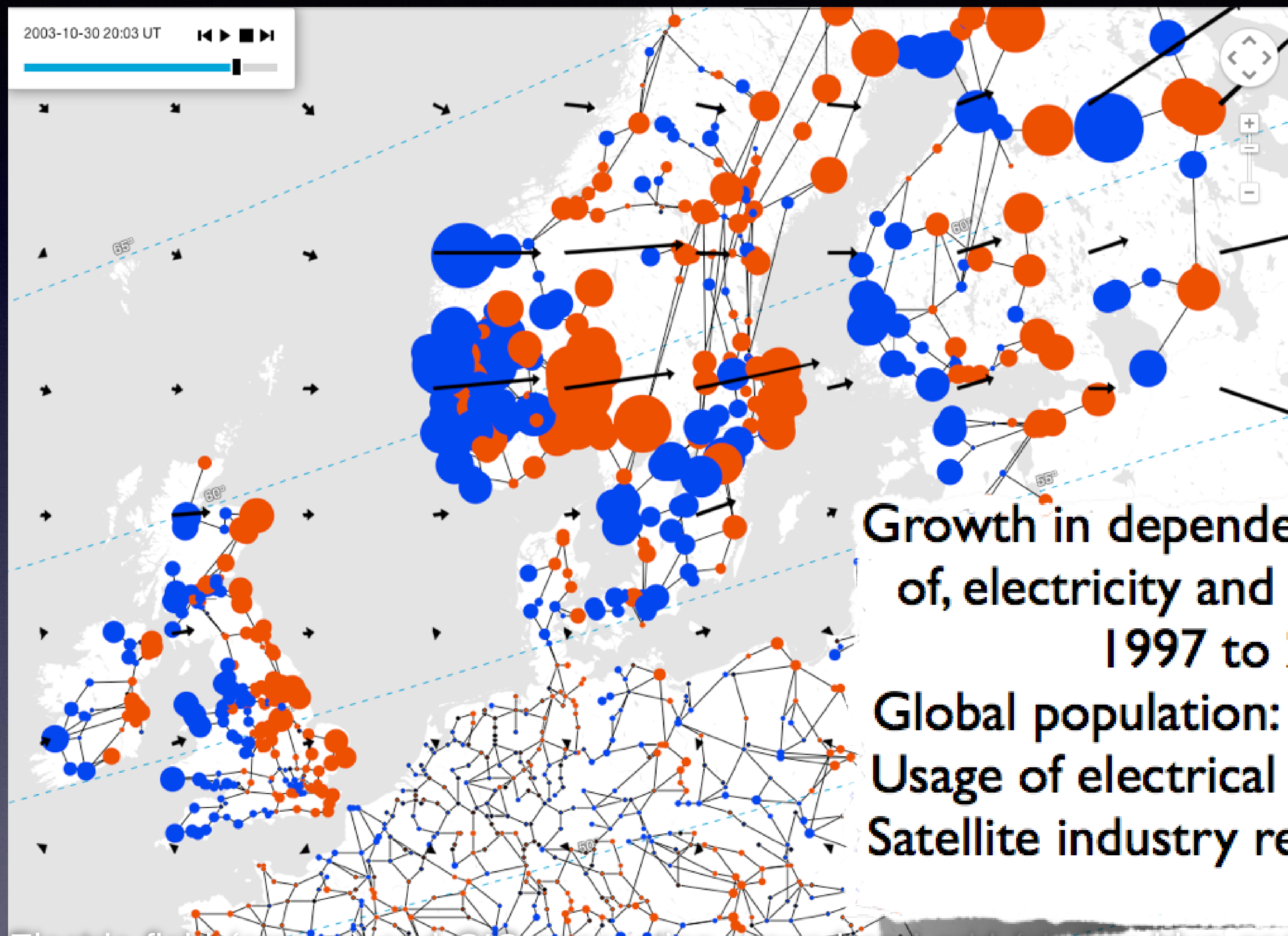
Some 80% of subscribers anticipate moderate to very strong consequences of a G5-class geomagnetic disturbance:



Expected impacts of an extreme GMD event if no action taken (compl.)

Schrijver and Rabanal, 2013, Space Weather Journal doi:10.1002/swe.20092

Geomagnetic variability and grid disturbances



Growth in dependence on, and use of, electricity and satellites from 1997 to 2012:

Global population:	+20%
Usage of electrical power:	+60%
Satellite industry revenue:	+420%

Electric field (arrows) and GIC connecting ground and grid (circles; blue and red for opposite directions), computed from dB/dt and a model grid configuration, for the 2003/10/30 Halloween storm a few minutes before the failure in power delivery in Southern Sweden (Malmö). Courtesy Ari Viljanen.

data visualization

Lou Lanzarotti (2008; doi:10.1029/2007SW000385)

- “To date, only a very few technical papers and discussions in this journal and elsewhere have addressed economic issues in space weather. And those that do have tended not to address the economics of design decisions. **I consider the absence of economic understanding of space weather impacts a serious missing link between space weather research and its applications.** Considerations of space weather and its importance to commerce and society must become more interdisciplinary in a broad sense: Economists must become interested and involved in providing the types of assessments that can aid in defining research directions and mitigation procedures.”

Space-weather impacts:

"What are the societal and economic impacts of severe space weather? [...] While this workshop, along with its report, has gathered in one place much of what is currently known or suspected about societal and economic impacts, it has perhaps been most successful in illuminating the scope of the myriad issues involved, and the gaps in knowledge that remain to be explored in greater depth than can be accomplished in a workshop. A quantitative and comprehensive assessment of the societal and economic impacts of severe space weather will be a truly daunting task [...]"

"[...] ***an estimate of $1 trillion to $2 trillion during the first year alone was given for the societal and economic costs of a "severe geomagnetic storm scenario" with recovery times of 4 to 10 years.***"

Potential Impacts of a major geomagnetic storm

- For a “Quebec- and Carrington-like” event: Assuming 10% of electricity supply is lost for one year, with Leontief’s input-output (IO) theory and associated tables:
  - American storm: US$ 2.4 trillion
  - European storm: US$ 3.4 trillion
  - Asia-centered storm: US$ 3.1 trillion

“The global economic damage is of the same order as wars, extreme financial crisis and estimated for future climate change.”

From H. Schulte in den Bäumen, D. Moran , M. Lenzen, I. Cairns, and A. Steenge; Nat. Hazards Earth Syst. Sci., 14, 2749–2759, 2014 Nat. Hazards Earth Syst. Sci., 14, 2749–2759, 2014

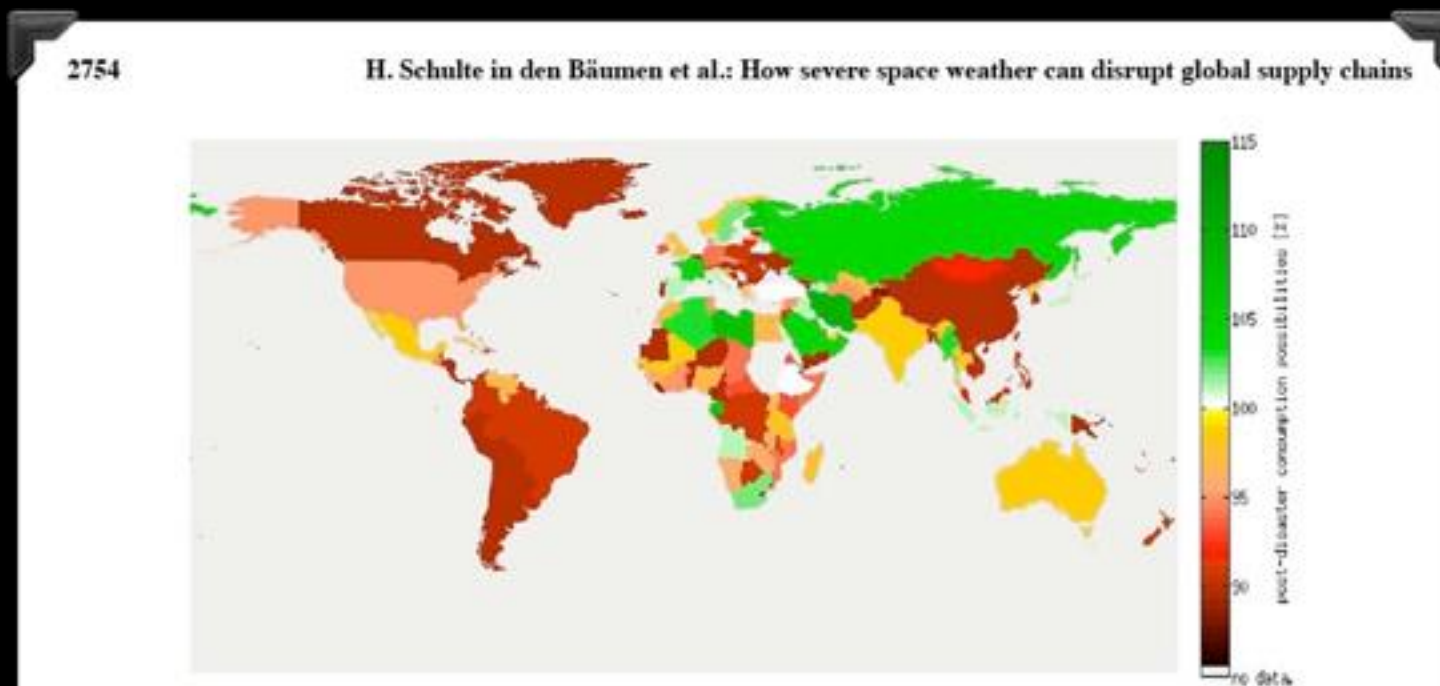
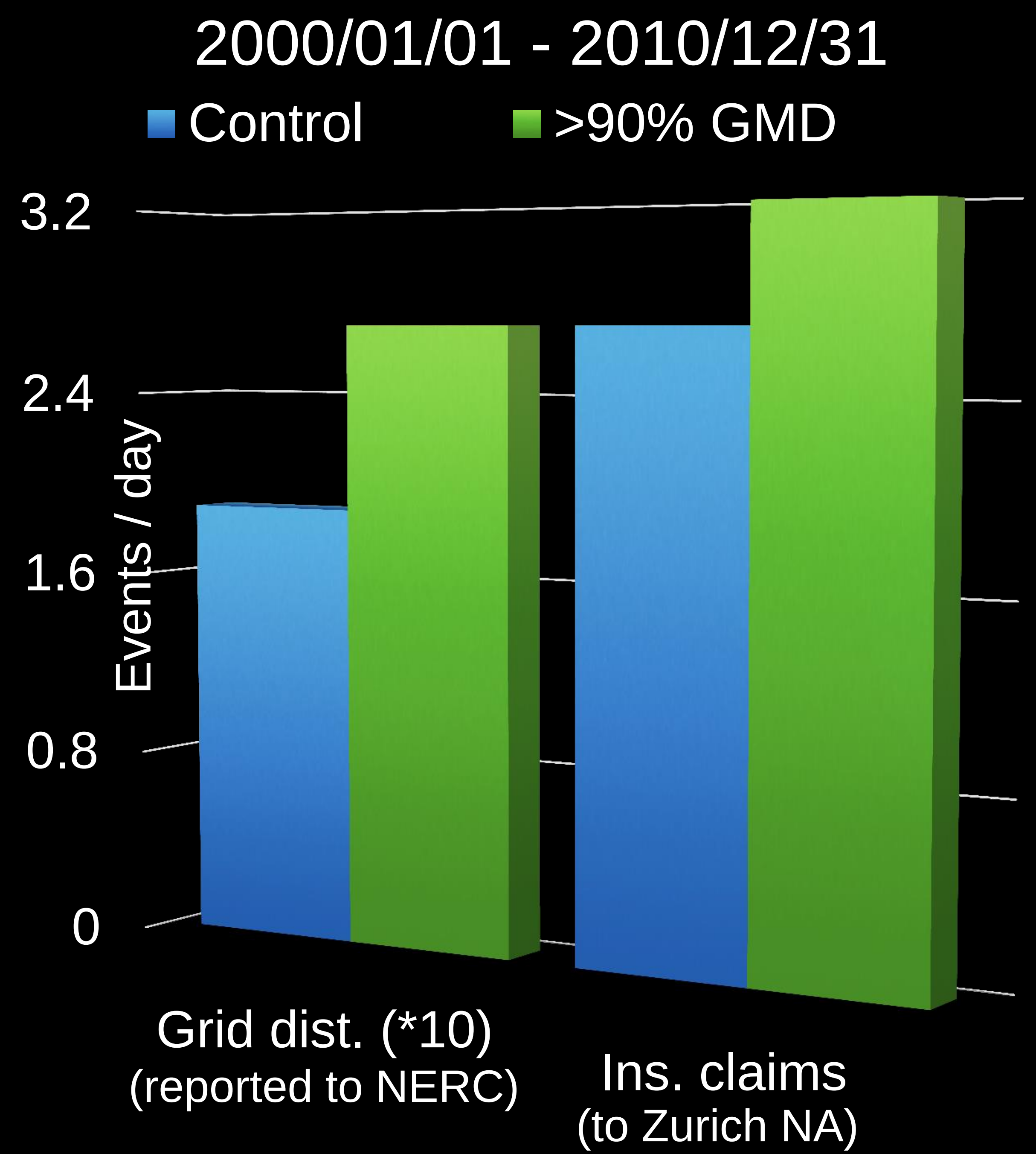


Figure 3. Effects of scenario 1, a Quebec 1989-like event centered over the Americas. Globally, the storm would reduce total consumption possibilities by 3.9 % though the effect is uneven: it is most severe in countries directly affected and their economic partners, while other countries (e.g., Russia, Saudi Arabia, France, and Egypt) may gain consumption possibilities in the post-disaster economy.

Effects of GMD on US power grid

- The ‘moderate’ geomagnetic storms of the past decade have impacts on the power grid and on the economy through ‘grid disturbances’ and insurance claims: it does not take a major storm for measurable effects:

- On top 10% of geomagnetically active dates; ~20% increase in insurance claims.



From C. J. Schrijver, R. Dobbins, W. Murtagh, and S. M. Petrinec; Space Weather, 2014 DOI 10.1002/2014SW001066

Example of impacts: power grids

Grid disturbance reports and insurance claims reveal that geomagnetic disturbances contribute to, if not directly cause, power-quality variations with economic impacts, even in non-extreme conditions.

Estimated impacts of "power outages and power quality disturbances" to the overall economy:

US: *US$100–180 billion/year* (from a study commissioned by the US Electric Power Research Institute, 2001)

25-country EU: approx. *€ 150 billion/year* (from a study by Manson and Targosz, 2008)

GDP impacts of common space weather via low-voltage electrical grid inferred via insurance claims for electrical/electronic industrial equipment is likely ~5% of total, i.e., *~US$5–10 billion/year*.

[roughly comparable to the total of a century-level extreme event!]

Schrijver (LMATC), Dobbins (Zurich NA), Murtagh (NOAA/SWPC), Petrinec (LM STAR Labs), 2014, Space Weather Journal

How severe can space weather storms be?

- Observations of Sun-like stars suggest that solar flares may reach energies up to 100-300 times above those observed in the past four decades.
- Ice and rocks from Earth and Moon tell us that energetic particle storm intensities appear to saturate at a few times the space-age maximum.
- Theory of geomagnetic storms suggests they may not be able to exceed twice the strength of the powerful 1859 Carrington event *(which may not be as rare as once thought: consider the 2012/07/23 heliospheric storm that missed Earth*)*, at least not when using Dst as a metric.

All these potential extremes exceed the levels to which modern technologies, connected in a network of growing complexity, have been exposed.

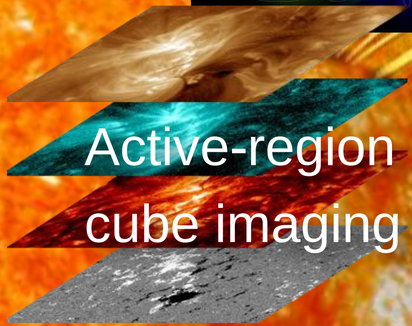
Reviewed by Schrijver & Beer, 2014; EOS, v. 95, no. 24, pp. 201-208

* Baker et al., 2013, Space Weather Journal, **DOI:** 10.1002/swe.20097: "extreme space weather conditions such as those during March of 1989 or September of 1859 can happen even during a modest solar activity cycle"

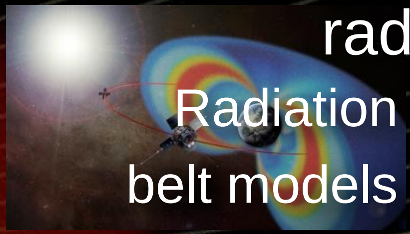
International roadmap

Deployment of new/additional instrumentation, to add to existing observational resources and to modeling capabilities to be developed soon:

I-1: Quantify active-region magnetic structure for nascent coronal ejections

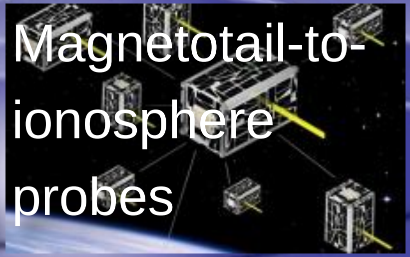


II: Data-driven dynamic radiation-belt modeling

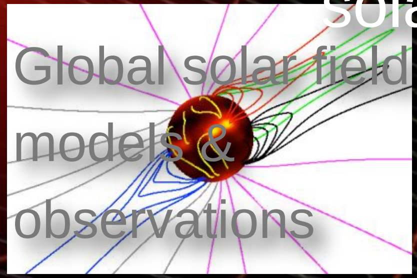


III: Solar energetic particles in the Sun-Earth system

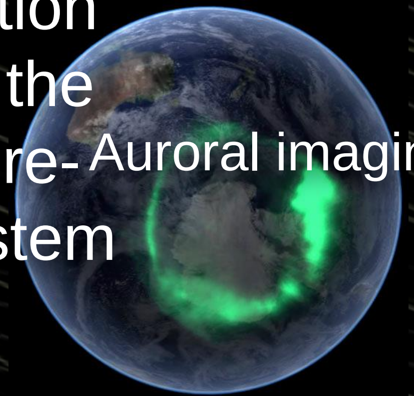
I-2: Solar wind-magnetosphere-ionosphere coupling inducing strong GICs



I-3: Global corona to drive models for the solar-wind plasma and field



I-4: Quantification of the state of the magnetosphere-ionosphere system



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